SITE: Carrier Air
BREAK: 7.8
OTHER: V2

TECHNICAL MEMORANDUM

Site Downgradient Monitoring Well Data Quality Assessment

Prepared for:

Carrier Corporation
Collierville, Tennessee

Prepared by:

Environmental and Safety Designs, Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901) 372-7962

October 18, 1994

10663220

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EXECUTIVE SUMMARY

It appears that migration of groundwater contamination from a 1979 TCE (trichloroethene) spill at the Carrier Collierville site is being adequately contained by two production wells owned and operated since 1969 at the northwest corner of the site by the Town of Collierville. This assessment is based on initial sampling of two new downgradient monitoring wells and groundwater modeling. Samples from the two monitoring wells, installed approximately 1000 feet northwest of the Collierville wells, did not contain TCE, which they would have if TCE from the spill site had migrated past Collierville's wells.

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1.0 PURPOSE

This technical memorandum presents the results of recent sampling at two downgradient monitoring wells. The monitoring wells were installed and sampled to determine whether two Town of Collierville (Water Plant 2) production wells located between the site of a spill at the main plant area and the monitoring wells have adequately contained groundwater contaminated with TCE. The second purpose of this memorandum is to assess whether data provided from sampling of the monitoring wells is adequate to form the basis for making the remedial decision about required scope of groundwater containment actions. This assessment focusses on two issues.

The first is whether the wells are properly located to intercept groundwater flowing past Collierville's production wells. This report reviews the procedures used to calibrate the groundwater flow model and confirm that the wells are located appropriately. Location of the monitoring wells was based on previous aquifer testing and groundwater flow modeling. The new monitoring wells were intended to confirm capture by the production wells at both the horizontal and vertical extent of the groundwater contaminant plume observed during the earlier remedial investigation. Until the new monitoring wells were installed and hydraulic levels measured, it was not possible to confirm which way groundwater flowed downgradient of the production wells. This document therefore presents a review of groundwater flow model calibration conducted (with new data from new wells included) to confirm that these wells are located appropriately.

The second issue is whether samples from the monitoring wells would contain TCE, if the production wells were not containing the contaminant plume. That is, would the TCE contamination have had enough time to migrate from the site of the 1979 TCE spill at the main plant area past the production wells and continue another 1000 feet to the monitoring wells?

As is detailed in this document, both initial sampling and modeling indicate that capture is being maintained at current pumping rates at Water Plant 2. Based on these results, Water Plant 2 is sufficient to meet remedial goals. The memorandum is thus concluded by an outline of the resulting scope of groundwater remedy design-presentation of as-built drawings and operating protocol for Water Plant 2.

2.0 WELL INSTALLATION

Installation of MW-60, the deep monitoring well began on May 23, 1994, and was completed on June 3, 1994. A pilot borehole was advanced 60 feet deep and split-spoon samples were taken to verify the presence of clay for setting the 10-inch steel surface casing. Three split-spoon samples were taken at depths of 60-62, 62-64, and 64-67 feet. The first split-spoon yielded clay with some gravel, the second split spoon had poor recovery, and the third split spoon had 100 percent recovery with a stiff clay. The boring was then overdrilled with a 16-inch bit to a depth of 69 feet and the surface casing installed at 68.5 feet deep. The surface casing was then pressure grouted in place and allowed to set for three days. Drilling proceeded with an 8-inch bit through the grout at the bottom of the casing and into the Memphis Sand. Sand was encountered at 135 feet, and the boring completed 400 feet deep. A coarse sand was encountered from 365 to 375 feet, overlain and underlain by more fine sand. The well was screened from 365 to 385 feet with 0.010-inch slotted screen. Total completed depth of MW-60 is 385 feet.

On June 3, 1994, a geophysical log of the well was run using a resistivity, spontaneous potential, gamma ray and neutron probes. The data generated from these probes were used to select the screen interval and placement of the ensuing monitoring well (MW-62). Copies of the geophysical logs of MW-60 are included with this memorandum as Appendix A.

The shallower monitoring well, MW-62, was installed from June 7, 1994 to June 13, 1994 approximately 25 feet west of MW-60. Drilling and installation methods for MW-62 were identical to those of MW-60, except that split-spoon samples of clay were omitted. The total depth of MW-62 was 200 feet with the screened interval located from 180 to 200 feet. The screened interval was selected based on screen locations of the Collierville wells and information obtained from the geophysical log of MW-60 which indicated a hard packed sand beginning at 285 feet.

Each monitoring well was completed flush to ground surface with a bolt-down manhole cover and sloping concrete pad. Construction well diagrams of MW-60 and MW-62 are Figures 1 and 2.

Boring logs of the Town of Collierville production wells (Water Plant 2) indicate a clay thickness of approximately 60 feet compared to approximately 65 feet in MW-60. Collierville well logs show the sands beginning at 136 to 140 feet and continuing to total depth with some clay lenses present. Boring logs from MW-60 and MW-62 show sand beginning at approximately 135 feet to termination depth, also with some clay present. Surface elevations between the Collierville wells and MW-60 and MW-62 differ by 1.73 to 2.93 feet.

0-25' SILTY CLAY

25-31' SAND, BROWN, F-MED GRAINED

31-38' GRAVEL 1/2 TO 1-INCH DIAMETER

38-45' SAND, BROWN F-MED GRAINED

45-50' SAND, BROWN COARSE GRAINED

50-62' GRAVEL PEA SIZE TO 1 1/2 DIAMETER

62-64' (SPLIT SPOON) RECOVERED 10" STIFF RED, MAROON, TAN SILTY CLAY W/LIMONITE

64-66' (SPLIT SPOON) NO RECOVERY PLUGGED SHOE W/ GRAVEL

67-69' (SPLIT SPOON) RECOVERED 24' CLAY

69-75' CLAY

75-85' CLAY W/POSSIBLE GRAVEL

85-135' SILTY CLAY POOR RECOVERIES

135-225' SAND, TAN, FINE TO COARSE GRAINED, TR. FELDSPARS AND LIMONITE STAINING

225-285' SAND, WHITE, VERY FINE TO FINE GRAINED WITH WHITE CLAY BALLS

285-345' SAND, WHITE, VERY FINE TO FINE GRAINED HARD PACKED

345-375' SAND, WHITE, VERY FINE TO FINE GRAINED WITH CLAY

375-390' SAND, TAN, FINE TO MED. W/TR. COARSE GRAINED W/HEMATITE & LIMONITE COATINGS

390-400' SAND, WHITE, VERY FINE TO FINE GRAINED TR. MED.

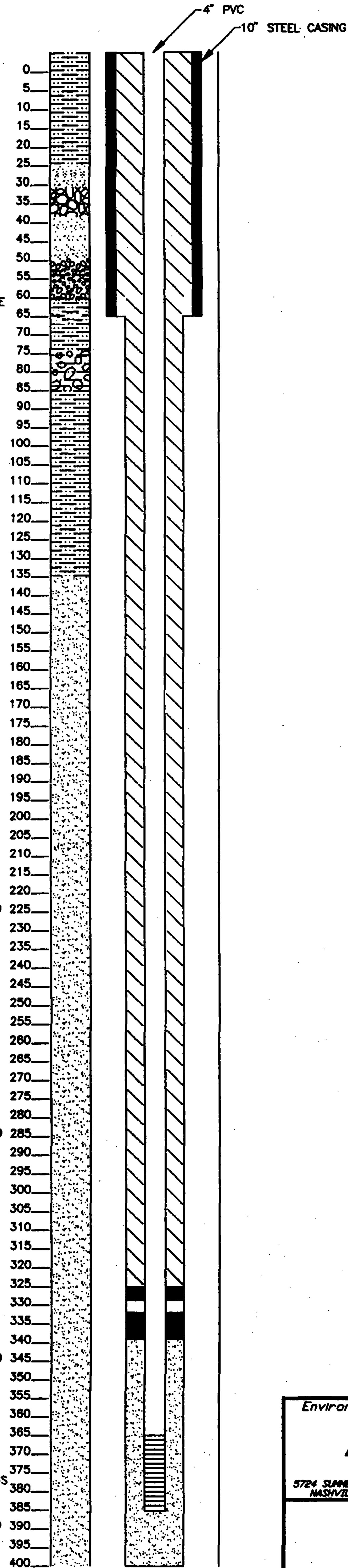

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FIGURE 1

MW-60

CARRIER COLLIERVILLE

DWG DATE: 08/09/94 | DWG NAME: CARRCOL2

0–25' SILTY CLAY

27–37' GRAVEL WITH FINE–MEDIUM GRAINED SAND

38–50' SAND, BROWN COARSE GRAINED

50–58' GRAVEL, PEASIZE TO 1–1/2 DIA.

58–65' CLAY, STIFF RED, MAROON, TAN SILTY CLAY

65–75' CLAY, STIFF PINK, TAN

75–90' CLAY, WITH POSSIBLE GRAVEL

90–105' SILTY CLAY, SOME SMALL GRAVEL

105–130' SILTY CLAY

130–150' SAND, TAN, FINE TO COARSE GRAINED
TR. FELDSPARS

150–175' SAND, TAN, MEDIUM GRAINED

175–190' SAND, MEDIUM TO COARSE GRAINED

190–200' SAND, TAN, FINE TO COARSE GRAINED

200–205' SAND, TAN, FINE TO COARSE GRAINED
TR. FELDSPARS

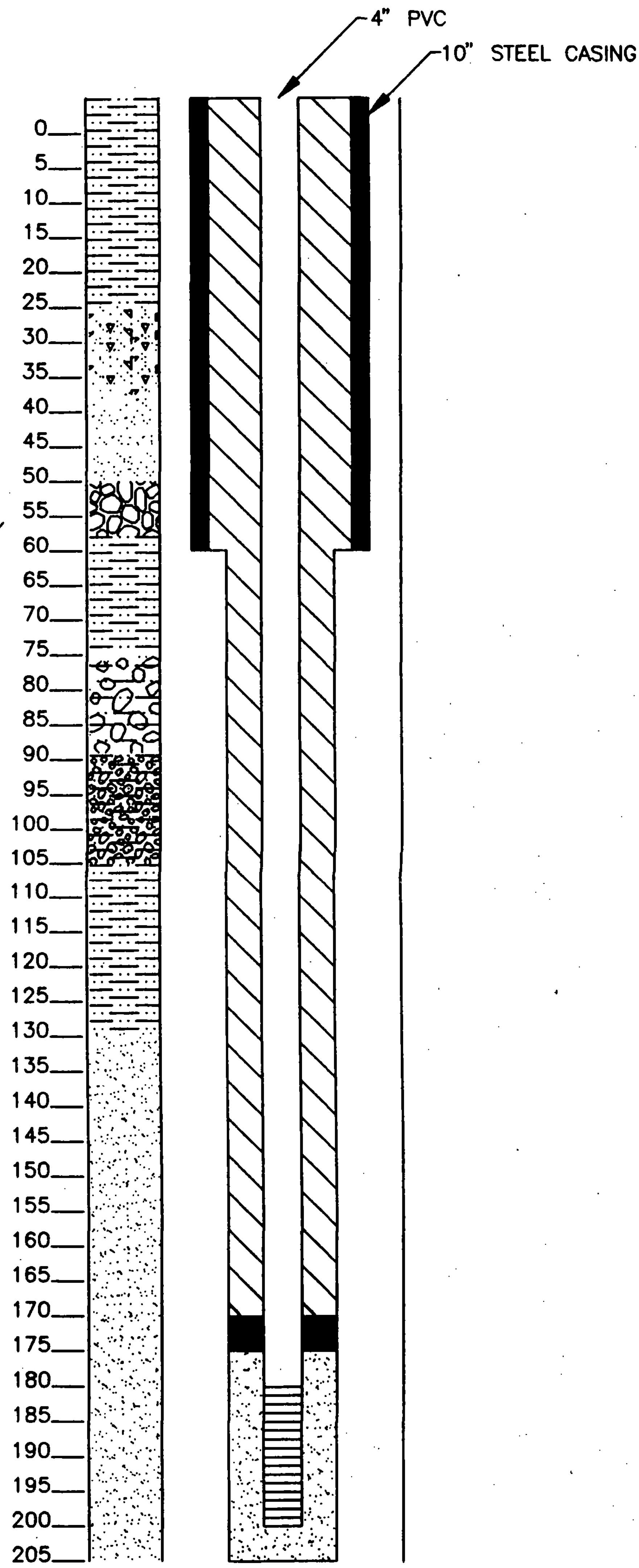

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FIGURE 2
MW–62
CARRIER COLLIERVILLE

DWG DATE: 08/09/94 | DWG NAME: CARRCOL1

3.0 FIRST QUARTERLY SAMPLING AND ANALYSIS

The quarterly groundwater monitoring program outlined in the remedial design work plan was implemented as soon as the new downgradient monitoring wells were developed.

3.1 Sampling Methods

Groundwater samples were collected as outlined in the remedial design work plan, from existing monitoring wells 3 and 58; new wells MW-60 and MW-62; the east and west Collierville wells; and from Water Plant 2 equipment. As in the past, both raw and after stripper, after aeration and after chlorination samples were obtained from Water Plant 2.

MW-60 and MW-62 were both purged of three casing volumes using a 2-inch stainless steel submersible pump. Stabilized measurements of temperature, pH, conductivity, and turbidity were obtained during purging of both wells. All purge water was contained in the onsite roll-off boxes for later disposal. The wells were then sampled using dedicated bailers.

MW-58 was purged and sampled using a previously installed bladder pump in the well. Again, three well volumes were purged and contained for later disposal, water quality measurements were taken, and stabilized readings achieved before sampling.

MW-3 was purged and sampled using a dedicated bailer. The well was bailed dry and allowed to recharge and then sampled.

Sampling protocol was followed on all sampling points as outlined in the remedial design work plan, Appendix C, Field Sampling Activities Plan.

3.2 Analytical Results

A total of 24 samples were submitted to PACE Laboratories at Minneapolis, Minnesota, for the analysis of volatile organic compounds, lead and zinc. The method references for these analytical parameters are listed below:

- USEPA Office of Solid Waste and Emergency Response, *Test Method for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), method number 6010 for the analysis of lead and zinc.

- The PACE method for the Low Level Volatile Organic Compounds is similar to the Contract Laboratory Program (CLP) Statement of Work *Low Concentration for Water, Volatile Organics Analysis* (10/92 version).

The first method is a common SW-846 method for analysis of metal analytes. Although both metals were analyzed using this method, lead was analyzed using a new Tracer inductively coupled plasma instrument capable of detecting analytes at concentrations comparable to an atomic absorption instrument. The lead analytical data have been reported down to the instrument detection limit of 3.0 $\mu g/\ell$.

The second method was developed by PACE Laboratories. This method was selected because it can detect a number of the volatile compounds at concentrations as low as 1 $\mu g/\ell$. The analytical procedures are similar to the CLP volatile organic compound method (version 3/90 SOW), except that the sample purge volume was increased to 25 mℓ to achieve the low detection limits. The CLP 3/90 SOW uses a 5 mℓ purge volume. The more recent version of the CLP SOW (10/92) also uses the 25 mℓ purge volume and similar analytical procedures to achieve the lower detection limits.

3.2.1 Results

Results of chemical analysis of the samples were as expected for all existing wells. The two new downgradient well samples did not contain TCE at detectable levels, nor Pb and Zn at concentrations above regulatory action limits (concentrations were similar to background concentrations seen during the RI). The results for contaminants of concern are summarized (from both neat and diluted analyses) in Table 1. The complete data summary tables are presented in Appendix B, and supporting calibration and analysis documentation is enclosed under separate cover.

Table 1 Sampling/Analytical Summary					Collierville Well/Water Plant 2				
Parameter, $\mu g/\ell$	MW3	MW58	MW60	MW62	East Well	West Well	After Stripper	After Aerator	After Chlorination
Trichloroethene	2000.0	1.0U	1.0U	1.0U	28.0	150.0	1.0U	1.0U	1.0U
1,2 Dichloroethene	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U
1,2 Dichloroethene (total)	760.0J	1.0U	1.0U	1.0U	1.0U	0.6J	1.0U	1.0U	1.0U
Tetrachloroethene	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U
Vinyl Chloride	1.0J	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
Lead	176.0	3.0U	3.0U	3.0U	4.70	3.0U	3.0U	3.0U	3.0U
Zinc	38500.0	15.0U	27.0	24.0U	38.0	43.0	11.0U	3.0U	7.0U

Analysis flags are as described in the remedial design work plan, Quality Assurance Project Plan: U signifies that the analyte was undetected; J signifies an estimate, with the analyte detected, but at an uncertain concentration.

3.2.2 Quality Assurance, Quality Control

3.2.2.1 Lead and Zinc

EnSafe Samples for Lead and Zinc Analysis
06179460
061794RB
061794CWW
061794AA
061794CWE
061794AS
06169462
061794AC
06179463 (EPA spike)
06179464 (EPA spike)
06209458
06209403

The samples analyzed for lead and zinc are listed in the table box to the right. All samples were received by the laboratory intact and with the proper custody documents. The sample designations indicate the date and area of collection. The first six digits of each sample designation denote the date of collection (e.g., 061794 is June 17, 1994) and the remaining two to three digits denote sample location.

The parameters reviewed during data validation indicated that the quality of the analyses was good. The only validation parameter found to potentially affect sample data was the reported presence of zinc in the laboratory and rinsate blanks. Analytical results for zinc in these two samples were 26.0 $\mu g/\ell$ and 5.0 $\mu g/\ell$, respectively. The laboratory blank was found to have had no effect on the sample data since the analysis run logs indicate that this blank was associated with the blank spike sample.

The rinsate blank is associated with the entire batch of samples and therefore it affects all samples. The means in which the *Contract Laboratory Program* allows the data validator to eliminate such contamination from the sample data is by the use of a 5-times rule. Essentially, the 5-times rule works by multiplying each compound concentration in the blank by five. This calculated concentration then becomes an action limit applied to the associated sample data by qualifying them as undetected if the sample concentration is less than the calculated limit. The associated samples with similar compound concentrations under the action limits are then assumed to be from an exogenous source. The samples with zinc concentrations under the calculated 25 $\mu g/\ell$ (5x5=25 $\mu g/\ell$ as the action limit) have been qualified as undetected. The affected samples were: 061794AA, 061794AS, 061794AC, 06179463, and 06209458.

3.2.2.2 Volatile Organic Compound Analysis

Eleven samples were submitted for the analysis of the volatile organic compounds. The sample identifications, including matrix spike and matrix spike duplicate, are listed in the text box to the right. All samples were received by the laboratory intact and with the proper custody documents.

EnSafe Samples for Volatile Compound Analysis
061694AA
061694AS
061694CWW
06169462
061694CWE
061794RB
061794AC
06179460
06209458
06209458D
06209458MS
06209458MSD
06209403

One sample (061794AC) was received by the laboratory and tested to have a pH of 6. Due to the neutral pH the laboratory had analyzed the sample within seven days after collection rather than 10 days (Note: SW-846 recommends a holding time of seven days for non-preserved samples for volatile analysis). The analytical data for this sample are not believed to have been affected by the pH.

Two samples in this sample delivery group were analyzed both neat and diluted because of concentrations of one or more volatile compounds. The initial analysis of sample 061694CWW indicated presence of trichloroethene at a concentration of 110 $\mu g/\ell$, which was above the calibrated range of the instrument. To quantitate the compound more accurately, the laboratory diluted (1:5 ratio with distilled water) and re-analyzed the sample extract. The re-analysis data are offered as sample 061694CWWDL with all compounds reported within the calibrated range of the instrument.

Note that the re-analysis does not report a concentration of 1,2-dichloroethene. This compound was reported in the initial analysis of sample 061694CWW. The 1,2-dichloroethene concentration was too dilute to be determined in reanalysis. The original sample data are suggested for observation of 1,2-dichloroethene concentration.

The second sample requiring diluted analysis was sample 06209403. This sample was found to contain higher-than-calibration-range concentrations of two volatile compounds: 1,2-dichloroethene (760 $\mu g/\ell$) and trichloroethene (650 $\mu g/\ell$). This sample was diluted by a factor of 1:100. This data are offered as sample 06209403DL. Note that carbon disulfide, 1,1-dichloroethene, and tetrachloroethene were diluted below detection in the reanalysis of sample 06209403.

The quality control blank data consisted of five laboratory method blanks and one field-derived rinsate blank (061794RB). The laboratory method blanks contained various concentrations of acetone with a range of 1 to 5 $\mu g/\ell$. One method blank also contained 2 $\mu g/\ell$ 2-butanone.

Acetone and 2-butanone are frequently used in the environmental laboratory and are thus often found in sample data due to their volatile nature. The *Contract Laboratory Program* allows the data validator to eliminate such contaminants from the sample data by the use of a 10-times rule. Essentially, this rule allows flagging these contaminants in any sample in which the concentration is no more than 10 times the highest occurrence in a blank. This has the effect of eliminating common laboratory artifacts from the sample data, as is the case with this project for acetone. The 2-butanone concentration was only found in the blanks and therefore was not a concern.

The rinsate blank also contained concentrations of acetone and 2-butanone similar to those detected in the method blanks. The rinsate blank contaminants were also applied to the associated sample data using the 10-time rule (Note: the associated sample data are the entire project sample set for the rinsate blank). Tetrachloroethene was also present in the rinsate blank at a concentration of 1 $\mu g/\ell$. Tetrachloroethene is not considered a common laboratory artifact and is believed to have been derived from the site or sampling equipment. In review of the sample data, only sample 06209403 was found to contain tetrachloroethene (also at a concentration of 1 $\mu g/\ell$). The rinsate blank is therefore believed to have been contaminated from the 06209403 sample source. Since tetrachloroethene contamination was not present in any other samples, no action was applied to the sample data.

3.2.2.3 Water Level Measurements

Water level measurements were taken after reaching the Memphis Sand aquifer in monitoring wells 60 and 62. Initial depth-to-water in MW-60 was 52 feet. Upon completion of MW-60, the depth to water had stabilized and dropped to approximately 80 feet. Water level measurements were taken in both wells before to purging to check for a vertical gradient. The two measurements indicated a slight downward vertical gradient between the two wells. The head difference between the two wells during measurements averaged 0.2 feet.

The screened interval in MW-60 begins at 70 feet below the completion depth of the east Collierville well and 86 feet below the completion depth of the west Collierville well. The completion depth of MW-62 is 75 feet above the top of the screen in the east Collierville well, and 39 feet above the top of the screen in the west Collierville well.

4.0 GROUNDWATER TRANSPORT MODELING

Confirmation modeling was conducted (1) to compare the potentiometric surface used during initial modeling (to choose downgradient monitoring well location) with new water level data that included measurements from the new wells, and (2) to assess groundwater travel times from the spill area and the Collierville wells to the new well locations.

Specifically, the modeling tasks were as follows:

- Collection of current pumping water level data at calibration points (June 30, 1994) using measurements at from existing monitoring wells (CURRENT.DAT) and MW-62 (NEW62.DAT).

- Comparison of current calibration points (CURRENT.DAT) with CAPZONE-generated surface (THEO.GRD). THEO.GRD is a result of assigning model drawdowns to the static water level map obtained during the 1992 aquifer pumping test (MOD2.GRD)

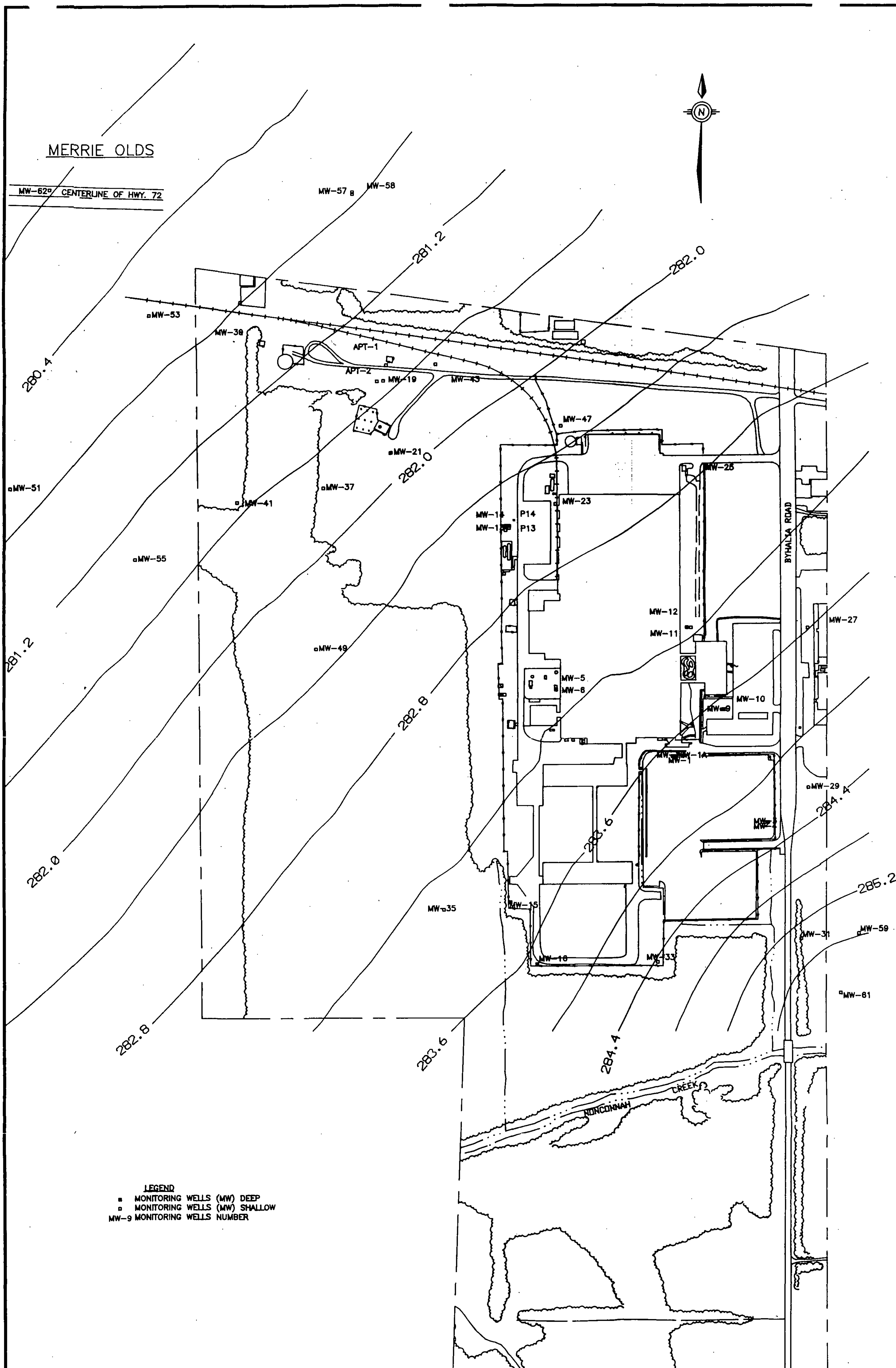
- Comparison of theoretical heads (THEO.GRD) at calibration points in NEW62.DAT

  — If the grid calibrated well, the original static potentiometric surface obtained during the aquifer test is representative of current aquifer conditions and may be used for modeling travel times to MW-62
  — If the grid did not calibrate well, the original static potentiometric surface did not adequately represent conditions northwest of the Collierville wells and a new static surface will be required

- Assessment of travel time for a particle to skirt the western edge of the containment zone and migrate into MW-62.

The current pumping water level surface was developed from data obtained on June 30, 1994. This file was named CURRENT.DAT. Coordinates and water level elevations for MW-62 were added to this file to create NEW62.DAT.

The static water level surface MOD2.GRD was created using SURFER and the Kriging method of interpolation; MOD2.GRD is presented in Figure 3. A diskette copy of the files used to conduct the modeling are enclosed with this memorandum. Water levels are presented for comparison in Table 2.



350 0 350

SCALE FEET

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FIGURE 3
MOD2.GRD POTENTIOMETRIC SURFACE
CONTOUR INTERVAL 0.4FT
CARRIER COLLIERVILLE

DWG DATE: 09/27/94 | DWG NAME: CRNEW1FB

Table 2
Measured Water Level Data (ft msl)

Well	Easting	Northing	Static Elevations September, 1992 (MOD2.GRD)	East Well Test Pumping Elevations September 1992	Two-Well Test Pumping Elevations September 1992	June 30, 1994 Pumping Elevations (NEW62.GRD)
MW-1	9572.30	8599.61	283.68	283.40	283.19	282.72
MW-4	9926.60	8352.93	284.14	283.95	283.82	283.49
MW-10	9756.99	8783.99	283.67	283.40	283.20	282.69
MW-12	9616.85	9096.22	283.13	282.79	282.45	281.96
MW-14	8929.51	9478.77	282.61	281.85	280.84	280.06
MW-16	9052.00	7814.29	283.64	283.42	283.36	282.99
MW-58	8353.85	10751.20	280.75	279.97	279.92	278.86
APT-1	8482.92	10090.60	281.48	280.09	278.99	278.39
APT-2	8448.43	10028.70	281.51	280.27	279.12	278.51
MW-62	7204.04	10761.55	—	—	—	277.94

4.1 CAPZONE Assessment

As with previous modeling efforts at this site, a semi-analytical model, CAPZONE, was then applied to simulate current pumping conditions. Aquifer parameters and operating conditions were defined as shown below:

Transmissivity	300,000 gpd/ft
Storativity	0.0014
Theis solution	confined aquifer
East well flow rate	375 gpm
West well flow rate	375 gpm
Pumping duration	30 days

Aquifer properties were calculated from the CAPZONE model calibration performed in February, 1994 (using data from the September 1992 test). Pumping rates were assumed from a typical 750 gpm average extraction rate for Water Plant 2. The pumping duration was assumed to be 30 days (i.e., long term). Data received July 14 indicate that the true monthly average was 764 gpm.

These data were used to create a pumping water level surface. This surface was then superimposed onto the static water level surface MOD2.DAT obtained during the September 1992 aquifer test and used for preliminary modeling in February, 1994. This theoretical surface was generated from the CAPZONE model in a SURFER grid file compatible format (THEO.GRD).

The theoretical pumping surface was then compared to the water level surface observed on June 30, under pumping conditions. Nine points on the surface were compared, each point representing a well location. The well locations compared are the following:

- MW-1
- MW-4
- MW-10
- MW-12
- MW-14
- MW-16
- MW-59
- APT-1
- APT-2

The theoretical pumping water level surface was higher in elevation than the current surface (e.g., between 0.7 ft and 1.5 ft higher). The mean absolute error (MAE) between these two files was 0.92 ft. In comparison, the original calibration in February, 1994 had a MAE of 0.18.

To check for the effect of pumping duration (whether the aquifer stabilizes), duration was set to 60 days and the model rerun. Once again, the theoretical surface was higher in elevation than the current surface, with an identical MAE of 0.92. No change in pumping water levels was observed due to the increase in duration, indicating that the aquifer has stabilized within 30 days of pumping.

4.1.1 Model Calibration

At least three possibilities may explain the difference between theoretical and current pumping water level maps:

- The static water level map used to develop the theoretical pumping surface was generated in 1992, and static water levels have changed since then—either seasonal or long term fluctuation.
- Extraction rates at Water Plant 2 have increased over the 750 gpm total flow estimate.
- The transmissivity and storativity calculated from 1992 aquifer test results are not fully representative of the aquifer.

To assess the sensitivity of the CAPZONE theoretical surface to each of these parameters, the static water level map, pumping rate, and transmissivity were altered. New theoretical pumping surfaces were generated and compared with the current water level map.

4.1.1.1 Static Water Level Map

The current and theoretical pumping water level files were compared to determine if there was any obvious justification for differences. Nine points on the maps were compared; these points correspond to the monitoring well and piezometer locations identified above. Elevations varied from 0.6 to 1.7 feet, with theoretical water levels consistently higher than levels measured on June 30, 1994. Seven of the nine locations varied between 0.61 and 0.83 feet.

Because the theoretical pumping surface is intrinsically tied to the static water level map MOD2.GRD, an artificial static surface was created to represent a water level surface 0.7 feet lower than MOD2.GRD. An offset of 0.7 feet was subtracted from each groundwater elevation in the file and used to generated a new theoretical surface, NEWSUR.GRD. This theoretical surface was then compared to the June 1994 surface. A MAE of 0.23 feet, comparable to the February, 1994 calibration of 0.18 feet, was calculated. Only wells APT-2 and MW-14 did not calibrate. This comparison strongly suggests that the explanation for differences between pumping water levels is a general or seasonal area-wide water level decrease. Such a decrease is not surprising, given the roughly two-year interval between water level measurements.

4.1.1.2 Pumping Rate

CAPZONE analyses were performed initially assuming a pumping rate of 1.08 million gallons per day (mgd) from Water Plant 2—375 gpm from each well. To assess the possibility of an increased pumping rate and the subsequent increase in drawdown, pumping rates were increased to 1.4 mgd, or 486 gpm from each well. This rate represents the maximum flow possible from Water Plant 2.

The theoretical pumping surface was generated with this increased flow rate. Drawdowns in the immediate vicinity of the well (APT-1, MW-58) increased on the theoretical pumping surface. However, outlying wells (MW-10, MW-12, MW-1, MW-4) were not impacted by this increase—the theoretical surface remained 0.7 foot higher than the current surface. The MAE for this analysis was 0.62.

Review of June 1994 Water Plant 2 pumping data (Appendix C) indicates that the rate had been fairly consistent throughout the month, with an average of 764 gpm, or 1.1 mgd. An increase in pumping rates, therefore, does not explain the water level differences.

4.1.1.3 Transmissivity

Finally, to assess the possibility that initial estimates of transmissivity and storativity were incorrect, transmissivity values were altered to determine potential impacts on the aquifer. Because the theoretical surface was higher than the current surface — potentially not exhibiting sufficient drawdown — the transmissivity of the aquifer was reduced from 300,000 gpd/ft to 250,000 gpd/ft. The MAE between theoretical and current pumping surfaces decreased to 0.77 foot. When the transmissivity was decreased again to 200,000 gpd/ft, the MAE decreased incrementally, to 0.61 foot.

In both transmissivity scenarios, drawdown in APT-1, APT-2, MW-58, and MW-14 increased (i.e., became closer in elevation to the current surface. However, no significant change was noted in outlying wells (MW-1, MW-4, MW-10, MW-12, and MW-16), in which the theoretical surface was still higher (0.58 to 0.72 foot) than the actual surface. Aquifer transmissivity calculated from the 1992 pump test (and subsequent model calibration) is most probably correct, and thus not the primary explanation for water level variances.

4.1.1.4 Model Calibration Conclusions

Although there are several different potential explanations for the discrepancy between theoretical and actual water levels, temporal fluctuation in hydraulic heads (seasonal or long-term) appears to be most plausible. The general offset in water levels of 0.7 foot has no material effect on use of the model to track contamination. The gradient between wells from location to location is what is of concern in flow modeling, not the change in levels over time. Consequently, the location of MW62 is sufficient for its intended purpose of detecting water from the western extent of the contaminant capture provided by the pumping of the west Collierville well.

4.1.2 Conditions at MW-62

The theoretical pumping surface was compared to the NEW62.DAT file to assess the difference between theoretical and current water levels at MW-62. The theoretical surface is 1 foot higher than the current surface. This difference, larger than the 0.7 foot noted throughout the discussion above, also indicates that the static surface (as represented by the SURFER algorithm) used to model the aquifer, MOD2.DAT, does not exactly represent water levels in the vicinity of MW-62. These data suggest that the static surface at MW-62 is lower than projected on MOD2.DAT, implying that the gradient steepens (is not uniform) downgradient of Water Plant 2. The implication is that the shape of the model-predicted capture zone downgradient of the Collierville wells would collapse slightly toward the wells. Although a set of contemporary static- and pumping-condition water level measurements could be performed (preferably during regular maintenance or an outage at Water Plant 2) the resulting data would not likely change the conclusion that MW62 is adequately located. Elective shut-down of Water Plant 2, for the 2-day period needed to assure equilibrium, was determined not to be necessary, considering summertime water demand and the value of the system as ongoing containment.

4.1.3 Contemporary Water Levels

This section is reserved for future discussion of contemporary static and pumping water levels to be obtained during the next regularly scheduled maintenance activity at Water Plant 2.

Table 3 and Figure 4 are reserved for presentation of these data.

4.2 Travel Time Assessments

The second task in validating suitability of the downgradient monitoring wells was to show whether contamination could be expected at the wells by now, if contamination was not contained by the pumping of Water Plant 2 wells. In other words, would TCE contamination have had enough time to migrate from the site of the 1979 TCE spill at the main plant area past the production wells and continue another 1000 feet to the monitoring wells?

Table 3
Contemporary Water Level Data (ft msl)

Well	Easting	Northing	Static Elevations	Pumping Elevations	CAPZONE-Generated Elevations	Residuals
MW-1	9572.30	8599.61				
MW-4	9926.60	8352.93				
MW-10	9756.99	8783.99				
MW-12	9616.85	9096.22				
MW-14	8929.51	9478.77				
MW-16	9052.00	7814.29				
MW-58	8353.85	10751.20				
APT-1	8482.92	10090.60				
APT-2	8448.43	10028.70				
MW-62	7204.04	10761.55				
MAE						

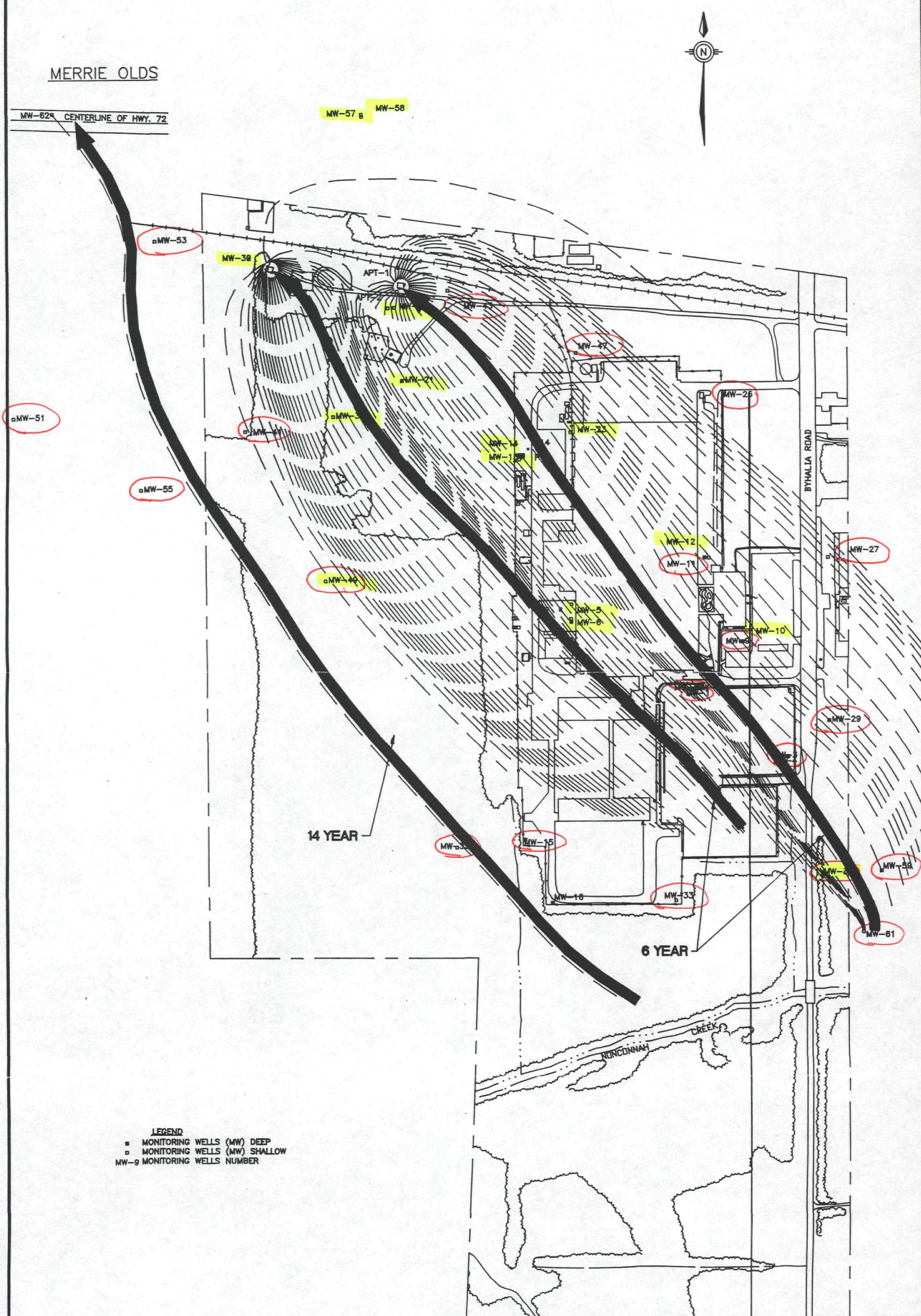
Figure 4 Contemporary Static Water Level Surface

To make this determination, additional modeling was conducted, this time using a CAPZONE-generated theoretical pumping surface as an entry to GW-Path, an advective particle tracking model similar to the Well Head Protection Algorithm (WHPA). In GW-Path, particle path-lines and advective flow velocities are tracked perpendicular to groundwater head contours using Darcy's Law.

Except for aquifer thickness, current values for aquifer characteristics, model calibration, and average pumping rates were used to assess TCE travel times from the source area at the main manufacturing plant. Instead of the assumed Memphis Sand thickness of 600 feet, an effective aquifer thickness of 200 feet was used. Much of the aquifer flow is through the more permeable interval of medium- to coarse-grained sand in the interval from about 90 to 290 feet below ground surface. This is based on logging and observation of aquifer material during installation of MW-60, and inspection of the boring logs for the production wells. Specifically, at MW-60 the limits are silts and clays (identified previously as the Jackson formation) at about 80-90 foot depth, and a transition to hard-packed very fined-grained sand at about 285 feet, per cuttings and the neutron log.

Although available information is less clear than for MW-62, drillers of the west Collierville well noted fine sand at 303 feet below ground surface, terminated the boring, and chose 281 feet as the bottom of the screened interval. Although the log for the east well does not specify sand particle size, drillers chose a similar depth interval for the screen, 278 to 298 feet below ground. Surface elevation of both Collierville wells and the downgradient wells are within a few feet. These observations thus lead to the conclusion that this stratigraphic feature (transition to very-fine sand at about 280-290 feet below ground surface) is persistent, at least in the area of the Collierville wells.

These boring log data were used to assess the feasibility of an **effective** aquifer thickness of 200 feet, constrained by stratographic distinctions within the Memphis Sand aquifer. No true aquitard or aquiclude probably exists, restricting flow in the plant vicinity. The partial penetration of the Collierville wells in the Memphis Sand likely results in some vertical flow from the lower (fine sand) zone. However, due to the distinction between grain size, it is apparent that the majority of flow will be derived from the upper 200 feet of the aquifer. The resulting new aquifer thickness, and the theoretical pumping surface (based on the available static water level map MOD2.GRD) were used to assess the travel time of a particle on the western edge of the west well capture zone migrating to MW-62. This pumping surface is thus based on an average pumping rate of 750 gpm shared by the two wells.



Environmental and Safety Designs, Inc.

EnSafe

5724 SUMMER TREES DR. MEMPHIS, TN. 38134 #(901)372-7962
NASHVILLE, TN, PENSACOLA, FL, AND RALEIGH, NC

FIGURE 5
ADVECTIVE PARTICLE TRANSPORT
CARRIER COLLIERVILLE

DWG DATE: 09/28/94 | DWG NAME: CRNEW1FA

Particles tracking into the Collierville wells and particles tracking along the western boundary of the capture zone are presented in Figure 5, which shows particle traces for two separate time-frames. First, the six-year track of particles travelling from the furthest point upgradient to the Collierville wells are depicted, superimposed on a six-year capture zone for Water Plant 2. This shows that advective flow could be expected to move contaminants from entry in the Memphis Sand aquifer at the main plant source area on or about 1980 to the Collierville wells in about 6 years. Thus the model agrees with site observations — the 1979 spill probably took a finite amount of time to reach the Sand, and began to manifest itself at the Collierville wells in 1986—travel across the site over a 6-year interval.

With that level of agreement, the model was also used to "reverse-track" a particle from MW-62 back for 14 years. As shown in the Figure, this trace also reaches to the entry point of contamination to the Memphis Sand near the main plant area and southern extent of the Jackson clay reported in the remedial investigation.

As to the vertical extent of contamination, MW-60 is due downgradient of both the source area and the west Collierville well. Travel times were not estimated as the effect of observed heterogeneity in aquifer materials at depth, and the occurrence, time and location of TCE migration to these depths preclude conclusive modeling.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions which can be drawn from the first groundwater sampling results and modeling assessment are as follows:

- MW-60 and MW-62 are adequate for the purpose for which they were intended, because:

  - They are located properly to serve as detector wells for water flowing to the west or under the capture zone of the Water Plant 2 production wells.

  - They would have exhibited TCE contamination by now, had Water Plant 2 not been providing capture of the plume.

- No TCE or degradation products are present in groundwater from MWs 60 and 62 (or 58). The Water Plant 2 treatment system continues to effectively treat groundwater from the production wells. Inorganic contaminants of concern are not present at concentrations above regulatory action limits in raw or treated Memphis Sand groundwater.

- Absence of contamination at MWs 60 and 62 indicate that capture is maintained at the current pumping rate of 750 gpm, shared by the two production wells.

On this basis, no additional groundwater extraction is needed to supplement the Collierville well field or the attendant treatment system. Continuation of the current extraction rates at Water Plant 2 is sufficient. No modification to the treatment system is necessary to meet the remedial action objective of preventing ingestion of groundwater contaminated at concentrations above Safe Drinking Water Act Maximum Contaminant Levels (MCLs). Further, the existing pump-and-treat system, operated with main plan area soil remediation (for which the pre-final design has been submitted to the EPA), will meet the objective of restoring water quality in the Memphis Sand to MCLs.

Given the above, design of the groundwater portion of the remedy for this site will consist of a presentation of the as-built design of Water Plant 2 pumping, treatment and auxiliary equipment, the performance standards verification plan and the operations and maintenance plan. The first plan will establish sampling protocol for the same monitoring points presented in the Remedial Design Work Plan. The operations and maintenance plan will document how a pumping rate of at least 750 gpm will be maintained, and the maintenance schedules for Water Plant 2 equipment, per the RD/RA Scope of Work.

A

APPENDIX A

GEOPHYSICAL LOGS

Submitted in Technical Memorandum dated August 12, 1994

APPENDIX B

ANALYTICAL DATA SUMMARY TABLES

CARRIER, COLLIERVILLE
SAMPLES

13205	SAMPLE ID ------->	CAR-G-0003-00	CAR-G-0003-00DL	CAR-G-0058-00	CAR-H-0058-00	CAR-G-0060-00	CAR-G-0062-00
	ORIGINAL ID ----->	06209403	06209403DL	06209458	06209458D	06179460	06169462
	LAB SAMPLE ID --->	13315.9	13315.9DL	13314.0	13311.6	13210.1	13211.0
	LAB REC DATE ---->	06/18/94	06/21/94	06/21/94	06/20/94	06/18/94	06/18/94
	UNITS ----------->	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
Method	Parameter						
VOA	Chloromethane	10.0000 U	1000.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U
VOA	Bromomethane	10.0000 U	1000.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U
VOA	Vinyl Chloride	1.0000 J	200.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	Chloroethane	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Methylene Chloride	2.0000 U	200.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	Acetone	14.0000 U	1000.0000 U	10.0000 U	10.0000 U	2.0000 U	3.0000 U
VOA	Carbon Disulfide	8.0000	300.0000 U	3.0000 U	3.0000 U	3.0000 U	3.0000 U
VOA	1,1-Dichloroethene	3.0000	200.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	1,1-Dichloroethane	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	1,2-Dichloroethene (total)	760.0000 J	1700.0000	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Chloroform	2.0000 U	200.0000 U	2.0000 U	2.0000 U	2.0000 U	0.9000 J
VOA	1,2-Dichloroethane	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	2-Butanone (MEK)	10.0000 U	1000.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U
VOA	1,1,1-Trichloroethane	2.0000 U	200.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	Carbon Tetrachloride	3.0000 U	300.0000 U	3.0000 U	3.0000 U	3.0000 U	3.0000 U
VOA	Bromodichloromethane	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	1,2-Dichloropropane	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	cis-1,3-Dichloropropene	2.0000 U	200.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	Trichloroethene	650.0000 J	2000.0000	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Dibromochloromethane	2.0000 U	200.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	1,1,2-Trichloroethane	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Benzene	2.0000 U	200.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	trans-1,3-Dichloropropene	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Bromoform	2.0000 U	200.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	4-Methyl-2-Pentanone	3.0000 U	300.0000 U	3.0000 U	3.0000 U	3.0000 U	3.0000 U
VOA	2-Hexanone	10.0000 U	1000.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U
VOA	Tetrachloroethene	1.0000	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	1,1,2,2-Tetrachloroethane	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Toluene	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	0.9000 J
VOA	Chlorobenzene	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Ethylbenzene	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Styrene	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Xylene (total)	1.0000 U	100.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U

CARRIER, COLLIERVILLE
SAMPLES

13205							
	SAMPLE ID ------->	CAR-G-0003-00	CAR-G-0003-00DL	CAR-G-0058-00	CAR-H-0058-00	CAR-G-0060-00	CAR-G-0062-00
	ORIGINAL ID ----->	06209403	06209403DL	06209458	06209458D	06179460	06169462
	LAB SAMPLE ID --->	13315.9	13315.9DL	13314.0	13311.6	13210.1	13211.0
	LAB REC DATE ---->	06/18/94	06/21/94	06/21/94	06/20/94	06/18/94	06/18/94
	UNITS ----------->	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
Method	Parameter						
VOA	Vinyl Acetate	10.0000 U	1000.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U

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07/27/94

CARRIER, COLLIERVILLE
SAMPLES

13205		CAR-G-00AA-00	CAR-G-00AC-00	CAR-G-00AS-00	CAR-G-00RB-00	CAR-G-0CWE-00	CAR-G-0CWW-00
	ORIGINAL ID ----->	061694AA	061794AC	061694AS	061794RB	061694CWE	061694CWW
	LAB SAMPLE ID --->	13205.5	13209.8	13207.1	13208.0	13206.3	13212.8
	LAB REC DATE ---->	06/18/94	06/18/94	06/18/94	06/18/94	06/18/94	06/18/94
	UNITS ----------->	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
Method	Parameter						
VOA	Chloromethane	10.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U
VOA	Bromomethane	10.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U
VOA	Vinyl Chloride	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	Chloroethane	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Methylene Chloride	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	Acetone	1.0000 U	2.0000 U	2.0000 U	6.0000 J	2.0000 U	10.0000 U
VOA	Carbon Disulfide	3.0000 U	3.0000 U	3.0000 U	3.0000 U	3.0000 U	3.0000 U
VOA	1,1-Dichloroethene	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	1,1-Dichloroethane	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	1,2-Dichloroethene (total)	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	0.6000 J
VOA	Chloroform	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	1,2-Dichloroethane	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	2-Butanone (MEK)	10.0000 U	10.0000 U	10.0000 U	1.0000 J	10.0000 U	10.0000 U
VOA	1,1,1-Trichloroethane	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	Carbon Tetrachloride	3.0000 U	3.0000 U	3.0000 U	3.0000 U	3.0000 U	3.0000 U
VOA	Bromodichloromethane	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	1,2-Dichloropropane	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	cis-1,3-Dichloropropene	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	Trichloroethene	1.0000 U	1.0000 U	1.0000	1.0000 U	28.0000	110.0000 J
VOA	Dibromochloromethane	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	1,1,2-Trichloroethane	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Benzene	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	trans-1,3-Dichloropropene	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Bromoform	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U	2.0000 U
VOA	4-Methyl-2-Pentanone	3.0000 U	3.0000 U	3.0000 U	3.0000 U	3.0000 U	3.0000 U
VOA	2-Hexanone	10.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U
VOA	Tetrachloroethene	1.0000 U	1.0000 U	1.0000 U	1.0000	1.0000 U	1.0000 U
VOA	1,1,2,2-Tetrachloroethane	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Toluene	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Chlorobenzene	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Ethylbenzene	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Styrene	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U
VOA	Xylene (total)	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U	1.0000 U

DATALCP2
07/27/94

CARRIER, COLLIERVILLE
SAMPLES

13205							
	SAMPLE ID ------->	CAR-G-00AA-00	CAR-G-00AC-00	CAR-G-00AS-00	CAR-G-00RB-00	CAR-G-0CWE-00	CAR-G-0CWW-00
	ORIGINAL ID ----->	061694AA	061794AC	061694AS	061794RB	061694CWE	061694CWW
	LAB SAMPLE ID --->	13205.5	13209.8	13207.1	13208.0	13206.3	13212.8
	LAB REC DATE ---->	06/18/94	06/18/94	06/18/94	06/18/94	06/18/94	06/18/94
	UNITS ----------->	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
Method	Parameter						
VOA	Vinyl Acetate	10.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U	10.0000 U

CARRIER, COLLIERVILLE
SAMPLES

13205							
	SAMPLE ID ------->	CAR-G-OCWW-OODL					
	ORIGINAL ID ----->	061694CWWDL					
	LAB SAMPLE ID --->	13212.8DL					
	LAB REC DATE ---->	06/21/94					
	UNITS ----------->	UG/L					
Method	Parameter						
VOA	Chloromethane	50.0000 U					
VOA	Bromomethane	50.0000 U					
VOA	Vinyl Chloride	10.0000 U					
VOA	Chloroethane	5.0000 U					
VOA	Methylene Chloride	10.0000 U					
VOA	Acetone	29.0000 U					
VOA	Carbon Disulfide	15.0000 U					
VOA	1,1-Dichloroethene	10.0000 U					
VOA	1,1-Dichloroethane	5.0000 U					
VOA	1,2-Dichloroethene (total)	5.0000 U					
VOA	Chloroform	10.0000 U					
VOA	1,2-Dichloroethane	5.0000 U					
VOA	2-Butanone (MEK)	50.0000 U					
VOA	1,1,1-Trichloroethane	10.0000 U					
VOA	Carbon Tetrachloride	15.0000 U					
VOA	Bromodichloromethane	5.0000 U					
VOA	1,2-Dichloropropane	5.0000 U					
VOA	cis-1,3-Dichloropropene	10.0000 U					
VOA	Trichloroethene	150.0000					
VOA	Dibromochloromethane	10.0000 U					
VOA	1,1,2-Trichloroethane	5.0000 U					
VOA	Benzene	10.0000 U					
VOA	trans-1,3-Dichloropropene	5.0000 U					
VOA	Bromoform	10.0000 U					
VOA	4-Methyl-2-Pentanone	15.0000 U					
VOA	2-Hexanone	50.0000 U					
VOA	Tetrachloroethene	5.0000 U					
VOA	1,1,2,2-Tetrachloroethane	5.0000 U					
VOA	Toluene	5.0000 U					
VOA	Chlorobenzene	5.0000 U					
VOA	Ethylbenzene	5.0000 U					
VOA	Styrene	5.0000 U					
VOA	Xylene (total)	5.0000 U					

CARRIER, COLLIERVILLE
SAMPLES

13205							
	SAMPLE ID ------->	CAR-G-OCWW-OODL					
	ORIGINAL ID ----->	061694CWWDL					
	LAB SAMPLE ID --->	13212.8DL					
	LAB REC DATE ---->	06/21/94					
	UNITS ----------->	UG/L					
Method	Parameter						
VOA	Vinyl Acetate	50.0000 U					

DATALCP2
07/27/94

CARRIER, COLLIERVILLE
SAMPLES

13213	SAMPLE ID ------->	CAR-G-0003-00	CAR-G-0058-00	CAR-G-0060-00	CAR-G-0062-00	CAR-G-0063-00	CAR-G-0064-00
	ORIGINAL ID ----->	06209403	06209458	06179460	06169462	06179463	06179464
	LAB SAMPLE ID --->	133213	133183	132136	132195	132217	132225
	LAB REC DATE ---->	06/21/94	06/21/94	06/18/94	06/18/94	06/18/94	06/18/94
	UNITS ----------->	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
Method	Parameter						
METAL	Aluminum						
METAL	Antimony						
METAL	Arsenic						
METAL	Barium						
METAL	Beryllium						
METAL	Cadmium						
METAL	Calcium						
METAL	Chromium						
METAL	Cobalt						
METAL	Copper						
METAL	Iron						
METAL	Lead	176.0000	3.0000 U	3.0000 U	3.0000 U	3.0000 U	78.0000
METAL	Magnesium						
METAL	Manganese						
METAL	Mercury						
METAL	Nickel						
METAL	Potassium						
METAL	Selenium						
METAL	Silver						
METAL	Sodium						
METAL	Thallium						
METAL	Vanadium						
METAL	Zinc	38500.0000	15.0000 U	27.0000	24.0000 U	24.0000	529.0000
METAL	Cyanide						

CARRIER, COLLIERVILLE
SAMPLES

13213							
	SAMPLE ID ------->	CAR-G-00AA-00	CAR-G-00AC-00	CAR-G-00AS-00	CAR-G-00RB-00	CAR-G-0CWE-00	CAR-G-0CWW-00
	ORIGINAL ID ----->	061794AA	061794AC	061794AS	061794RB	061794CWE	061794CWW
	LAB SAMPLE ID --->	132160	132209	132187	132144	132179	132152
	LAB REC DATE ---->	06/18/94	06/18/94	06/18/94	06/18/94	06/18/94	06/18/94
	UNITS ----------->	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
Method	Parameter						
METAL	Aluminum						
METAL	Antimony						
METAL	Arsenic						
METAL	Barium						
METAL	Beryllium						
METAL	Cadmium						
METAL	Calcium						
METAL	Chromium						
METAL	Cobalt						
METAL	Copper						
METAL	Iron						
METAL	Lead	3.0000 U	3.0000 U	3.0000 U	3.0000 U	4.7000	3.0000 U
METAL	Magnesium						
METAL	Manganese						
METAL	Mercury						
METAL	Nickel						
METAL	Potassium						
METAL	Selenium						
METAL	Silver						
METAL	Sodium						
METAL	Thallium						
METAL	Vanadium						
METAL	Zinc	3.0000 U	7.0000 U	11.0000 U	5.0000 J	36.0000	43.0000
METAL	Cyanide						

13213	SAMPLE ID ------->	CAR-G-BSPK-00					
	ORIGINAL ID ----->	BLANK SPIKE					
	LAB SAMPLE ID --->	132233					
	LAB REC DATE ---->	06/18/94					
	UNITS ----------->	UG/L					
Method	Parameter						
METAL	Aluminum						
METAL	Antimony						
METAL	Arsenic						
METAL	Barium						
METAL	Beryllium						
METAL	Cadmium						
METAL	Calcium						
METAL	Chromium						
METAL	Cobalt						
METAL	Copper						
METAL	Iron						
METAL	Lead	3.0000 U					
METAL	Magnesium						
METAL	Manganese						
METAL	Mercury						
METAL	Nickel						
METAL	Potassium						
METAL	Selenium						
METAL	Silver						
METAL	Sodium						
METAL	Thallium						
METAL	Vanadium						
METAL	Zinc	3.0000 U					
METAL	Cyanide						

APPENDIX C

JUNE 1994 PRODUCTION AT WATER PLANT 2

RECEIVED
JUL 14 1994

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER SUPPLY
Monthly Operation Report

NAME OF WATER UTILITY: TOWN OF COLLIERVILLE PWSID: 0000126
NAME OF WATER TREATMENT PLANT: WATER PLANT #2 COUNTY: SHELBY
MONTH OF: June 1994

DATE	WATER TREATED GALLONS x1000	CHLORINE POUNDS USED	CHLORINE MG/L FREE RESIDUAL	FLUORIDE GALS USED	FLUORIDE MG/L CALC'D DOSAGE	FLUORIDE MG/L DIST SYSTEM	ALKALINITY MG/L TOTAL RAW	ALKALINITY MG/L TOTAL FINISHED	pH SU RAW	pH SU FINISHED	CO2 FREE RAW	CO2 FREE FINISHED
01	1192	18.0	1.4	70.1	1.06	1.00	18	25	5.6	8.6	9	0
02	1281	19.0	1.4	73.5	1.03	1.00	18	25	5.6	8.6	9	0
03	1169	16.0	1.4	71.4	1.10	1.00	18	25	5.6	8.6	8	0
04	1160	17.0	1.4	72.4	1.10	1.00	18	24	5.6	8.6	8	0
05	1185	16.0	1.2	71.6	1.09	1.00	18	24	5.6	8.7	8	0
06	1211	17.0	1.2	74.1	1.10	1.00	18	24	5.6	8.7	9	0
07	1350	19.0	1.2	77.5	1.03	1.00	18	25	5.6	8.7	9	0
08	1367	18.0	1.2	79.1	1.04	1.00	18	25	5.6	8.6	9	0
09	1150	17.0	1.2	69.9	1.09	1.00	18	24	5.6	8.6	9	0
10	999	14.0	1.2	60.1	1.08	1.00	18	24	5.6	8.6	8	0
11	1050	15.0	1.2	62.2	1.07	1.00	18	24	5.6	8.6	8	0
12	1065	14.0	1.0	63.1	1.07	1.00	18	25	5.6	8.6	9	0
13	1078	13.0	1.0	64.0	1.07	1.00	18	25	5.6	8.7	9	0
14	1132	15.0	1.0	66.6	1.06	1.00	18	25	5.6	8.7	9	0
15	1221	14.0	1.0	69.5	1.02	1.00	18	24	5.6	8.7	9	0
16	1195	15.0	1.0	73.0	1.10	1.00	18	24	5.6	8.7	8	0
17	1206	16.0	1.0	74.4	1.11	1.00	18	24	5.6	8.7	8	0
18	1194	16.0	1.2	70.4	1.06	1.00	18	24	5.6	8.6	9	0
19	1201	17.0	1.2	71.0	1.06	1.00	18	24	5.6	8.6	9	0
20	1207	17.0	1.2	68.8	1.03	1.00	18	25	5.6	8.6	9	0
21	1186	16.0	1.2	66.1	1.00	1.00	18	25	5.6	8.6	9	0
22	1156	17.0	1.2	71.4	1.11	1.00	18	25	5.6	8.6	9	0
23	1516	24.0	1.2	93.1	1.11	1.00	18	25	5.6	8.6	9	0
24	1263	18.0	1.4	70.9	1.01	1.00	18	25	5.6	8.7	8	0
25	1050	16.0	1.4	63.1	1.08	1.00	18	25	5.6	8.7	8	0
26	1065	17.0	1.4	64.1	1.08	1.00	18	25	5.6	8.7	8	0
27	1089	16.0	1.2	62.5	1.03	1.00	18	25	5.6	8.7	8	0
28	1105	15.0	1.2	65.1	1.06	1.00	18	24	5.6	8.6	9	0
29	1171	14.0	1.2	67.5	1.04	1.00	18	24	5.6	8.6	9	0
30	1175	15.0	1.2	68.0	1.04	1.00	18	25	5.6	8.6	9	0
TOTAL	35409	491.0	36.2	2094.7	31.95	30.00	540	737	168.0	259.2	259	0
AVERAGE	1180	16.4	1.2	69.8	1.07	1.00	18	25	5.6	8.6	9	0
MAXIMUM	1516	24.0	1.4	93.1	1.11	1.00	18	25	5.6	8.7	9	0
MINIMUM	999	13.0	1.0	60.1	1.00	1.00	18	24	5.6	8.6	8	0

REMARKS:

Terry D. Williams
CERTIFIED OPERATOR: TERRY D. WILLIAMS

CERTIFICATE NUMBER: 1100

APPENDIX D

CAPZONE/GW-PATH ANALYTICAL SUMMARY

CAPZONE/GW-Path Analyses

The CAPZONE and GW-Path analytical flow models were used to evaluate groundwater flow and theoretical drawdown within the Memphis Sand at Carrier Collierville. The models were used to perform the following tasks:

- Derive aquifer parameters through calibration of theoretical drawdown to observed drawdown data.
- Evaluate capture zones for Water Plant 2 with respect to the source area.
- Assess travel times between the source area and Water Plant 2.

CAPZONE/GW-PATH

The CAPZONE (Version 1.1, March 1992) analytical process integrates three software programs. CAPZONE is the central program, which estimates drawdowns at the intersections of a regularly spaced horizontal grid according to Theis equation. The user may then either superimpose the drawdown grid on a uniform hydraulic gradient or on a regional piezometric surface map to represent theoretical pumping conditions within the aquifer. CAPZONE may also be used to model image wells and superposition of drawdown, therefore facilitating analyses of a bounded aquifer or a well system with one or more recovery/injection wells.

As CAPZONE is based on the Theis equation, the following assumptions are inherent to the analysis:

1. the aquifer is isotropic
2. the aquifer is homogeneous
3. the aquifer is infinite
4. radial flow is bounded by nonleaky-confining layers
5. the pumping well is fully-penetrating
6. extraction rates are constant
7. the pumping well has an infinitesimal diameter

GW-PATH (Version 4.0, 1990) is a groundwater pathline and travel time analysis program that computes the two-dimensional, steady-state velocity field at the intersections of a rectangular grid using distributions of hydraulic head, hydraulic conductivity, and effective porosity. Capture zones may be delineated using either forward- or reverse-particle tracking modules. GW-PATH receives CAPZONE output grids and uses them for particle tracking and capture zone analyses.

SURFER (Version 4.15, 1990) is the input/output program used to develop regional piezometric surface maps of the aquifer system. SURFER is capable of contouring piezometric surfaces using Krieging, Inverse-Distance, or Minimum Curvature algorithms. Potentiometric surface maps were derived from the static and pumping surfaces measured during the September, 1992 aquifer test. A second pumping surface was measured on June 30, 1994. All three maps were contoured using the SURFER program. The Krieging method was applied to Carrier data, as it most closely approximated the hand-contoured surface. SURFER is also one of the output programs available to evaluate CAPZONE and GW-PATH data. SURFER is used to view or print CAPZONE grids for evaluation. SURFER also processes GW-PATH *.PLT files into *.DXF files. *.DXF files may then be imported into AUTOCAD for viewing and/or plotting.

The CAPZONE/GW-PATH methodology offers two distinct advantages over similar analytical methodologies, such as WHPA-RESSQC or DREAM. First, the CAPZONE/GW-PATH method can be used to evaluate drawdown superimposed on a regional piezometric surface, to better represent actual aquifer conditions. Previously, superposition on a regional water level map was only possible through use of a three-dimensional, finite-difference flow model such as MODFLOW. Second, calibration of CAPZONE/GW-PATH using theoretical and observed drawdowns on a regional piezometric surface is facilitated through the use of SURFER utilities. Calibration of the CAPZONE model is achieved through a trial-and-error process in which pumping data is compared to theoretical drawdowns. The user may adjust aquifer parameters (T, S) and thus perform sensitivity analyses until the optimal match is found. Calibration is usually performed using both visual comparisons of pumping and theoretical data, as well as statistical analyses.

1.0 Input Requirements

CAPZONE

Input data required for CAPZONE analyses include aquifer parameters, pumping/injection well data, grid parameters, and either a uniform hydraulic gradient or a regional piezometric surface map. These parameters are summarized in Table 1.

GW-PATH

GW-PATH input parameters include definition of the flow domain, grid parameters, groundwater flow paramters, and a hydraulic head filename. If pathlines will be computed, the pathline type, start coordinates, and time increment must be provided. These parameters are summarized in Table 2.

Table 1 CAPZONE Input Parameters			
Parameter Group	**Parameter**	**Units**	**Definition**
Units	Input Units	metric or american	The user must define the units which will be used throughout input.
Aquifer Parameters	Solution Method	none	User must select Theis or Hantush Jacob solution.
	Transmissivity	gpd/ft	User must input the transmissivity.
	Storativity	unitless	User must input the storativity.
	Confined/ Unconfined	none	User must define aquifer as confined or unconfined
	Saturated Thickness	ft	User must define the saturated thickness of the aquifer
Pumping/Injection Well Parameters	Number of Wells	None	User must define the number of pumping/ injection wells to be analyzed.
	X,Y Coordinates	ft	The X and Y coordinates of each pumping well.
	Pumping/Injection Rate	gpd	The pumping or injection rate for each well (injection is negative).
	Pumping Duration	days	The duration of pumping for each well.
Grid Parameters	X,Y Start Coordinates	ft	X,Y start coordinates for grid.
	Nodes in X Direction	unitless	Number of grids in X direction.
	Increment in X Direction	ft	Delta X spacing between nodes.
	Nodes in Y Direction	unitless	Number of grids in Y direction.
	Increment in Y Direction	ft	Delta Y spacing between nodes.
Regional Piezometric Map/ Hydraulic Gradient	Regional Piezometric Map	None	The regional piezometric surface map upon which CAPZONE superimposes the theoretical drawdowns.
	Uniform Hydraulic Gradient	ft/ft	The gradient upon which CAPZONE superimposes the theoretical drawdowns.

Table 2
GW-PATH Input Parameters

Parameter Group	Parameter	Units	Definition
Flow Domain Parameters	Orientation	none	User must define either a horizontal (plane view) or vertical (cross-sectional) orientation.
	Length Units	m or ft	User must define units.
	Time Units	seconds, years, or days	User must define units.
	Plotfile Name	none	If the user wishes to generate a plot of the pathlines, a plotfile must be defined (*.PLT).
	Number of Nodes (X,Y)	none	The user must define the number of X and Y nodes in the grid.
	X,Y Start Coordinates	ft	The user must define the X and Y start coordinates.
	Increment in X Direction	ft	Delta X spacing between nodes.
	Increment in Y Direction	ft	Delta Y spacing between nodes.
Hydraulic Head File Name	File Name	unitless	The user must specify a hydraulic head file name to represent either a static or stressed piezometric surface on which to generate pathlines.
Pathline Analysis Parameters	Pathline Type/ Analysis Method	none	User must specify if forward or reverse pathlines will be used, or if capture zones will be identified.
	Start Coordinates	ft	The user must identify the start coordinates for pathline estimation.
	Number of Paths	none	The user must identify the number of pathlines to be used if delineating a capture zone.
	Total Time	years	The time duration of pathline analysis. Units must agree with those selected under flow domain parameters.
	Max/Min Time Step	years	The user must define the maximum and minimum time increments to be used in pathline estimation.
	Moves per Cell	none	The user must define the degree of resolution possible within a grid cell.

SURFER

SURFER requires a basefile to generate a regional piezometric surface map (called a *.GRD file). When SURFER is used as a CAPZONE output tool, CAPZONE must provide a *.GRD file. The basefile for SURFER must contain the X,Y coordinates of each point to be contoured, as well as a Z coordinate representing groundwater elevation. The basefile may be written within the SURFER program or imported as a ASCII text file, Lotus *.WK1 file, or a *.WKS file. The user, in the GRID mode, then defines the contouring method, the grid size, and grid limits prior to generation of the *.GRD file. The *.GRD file is then viewed, modified, or plotted using the TOPO mode of SURFER. Modifications in the TOPO mode will vary with the density and degree of refinement require for adequate assessment of the *.GRD file.

Note that CAPZONE and GW-PATH require somewhat different input, as well as requiring different units (ft^2/day or ft^2/year versus gpd/ft).

1.1 Application to Carrier Collierville: Compliance with Model Assumptions

The CAPZONE/GW-PATH analysis technique was reviewed for applicability to Carrier Collierville. The aquifer regime meets all assumptions inherent in the CAPZONE/GW-PATH programs except for the following:

- The aquifer is not 100 percent homogeneous.
- Pumping wells are not fully penetrating.

The aquifer changes from unconfined to confined conditions southeast of the TCE spill area. This boundary was approximated in CAPZONE using 2 image wells, according to standard image well theory.

The pumping well and observation wells are not fully penetrating. AQTESOLV was used to generate first estimates of transmissivity and storativity, as documented in the *East Well Aquifer Pumping Test Report*, dated December 14, 1992. The AQTESOLV calculations were performed using a partial penetration correction. No additional corrections were applied to calculations.

1.2 Application to Carrier Collierville: Input Parameters

The regional potentiometric surface map used in the CAPZONE/GW-PATH analyses were obtained from pre-pumping water levels measured in September 1992. Pumping water levels were developed using data from both the 1992 tests and from measurements made on June 30, 1994.

Tables 3 and 4 show the input variables used in CAPZONE and GW-PATH analyses.

Table 3
Input Parameters — CAPZONE

Parameter Group	Parameter	Units	Memphis Sand Data
Units	Input Units	metric or American	American
Aquifer Parameters	Solution Method	none	Theis
	Transmissivity	gpd/ft	300,000
	Storativity	unitless	0.014
	Confined/ Unconfined	none	Confined
	Saturated Thickness	ft	200
Pumping/Injection Well Parameters	Number of Wells	None	4
	X,Y Coordinates	ft	East: 8497, 10109 West: 8014, 10176 Image East: 11465, 6809 Image West: 11496, 6320
	Pumping/Inject-ion Rate	gpd	540,000
	Pumping Duration	days	30
Grid Parameters	X,Y Start Coordinates	ft	6500, 6000
	Nodes in X Direction	unitless	56
	Increment in X Direction	ft	100
	Nodes in Y Direction	unitless	61
	Increment in Y Direction	ft	100
Regional Piezometric Map/ Hydraulic Gradient	Regional Piezometric Map	None	MOD2.GRD
	Uniform Hydraulic Gradient	ft/ft	Not used

Table 4
Input Parameters — GW-PATH

Parameter Group	Parameter	Units	Memphis Sand Data
Flow Domain Parameters	Orientation	none	Horizontal
	Length Units	m or ft	feet
	Time Units	seconds, years, or days	years
	Plotfile Name	none	*varied with scenario*
	Number of Nodes (X,Y)	none	56, 61
	X,Y Start Coordinates	ft	6500, 6000
	Increment in X Direction	ft	100
	Increment in Y Direction	ft	100
Hydraulic Head File Name	File Name	unitless	*varied with scenario*
Pathline Analysis Parameters	Pathline Type/ Analysis Method	none	Reverse pathlines, circular origin
	Start Coordinates	ft	*varied with scenario*
	Radius of origin	ft	10
	Number of Paths	none	30
	Total Time	years	*varied with scenario*
	Max/Min Time Step	years	Max 0.1 Min 0.01
	Moves per Cell	none	2

2.0 CAPZONE Calibration

Model calibration was accomplished by comparing predicted drawdowns generated using CAPZONE with observed drawdowns measured during the September 1992 test. Initial aquifer parameters were obtained from the *East Well Aquifer Test Report*, dated December 14, 1992. Aquifer parameters were evaluated in an iterative fashion until predicted and observed drawdowns agreed within a relative degree of certainty. Calibration calculations performed during February, 1994 showed predicted and observed drawdowns were within 0.18 ft mean absolute error (MAE). The geometric mean transmissivity calculated in the aquifer test report, 285,000 gpd/ft, compared favorably with the calibrated transmissivity, 300,000 gpd/ft. The storativities did not vary from 0.014 during the calibration.

3.0 Capture Zone Assessment

Once the calibrated transmissivity was obtained, capture zones for both the east and west wells were generated. The primary objective of capture zone assessment was to determine the downgradient extent of Water Plant 2's capture zone and the breadth of the capture zone cross-gradient.

The shape of the capture zone is highly dependent upon the steepness of the hydraulic gradient between Water Plant 2 and MW-62. In general, the steeper the gradient, the more the capture zones will collapse slightly towards Water Plant 2 and the narrower its width. Water level data obtained on June 30, 1994 and compared with theoretical pumping water level surfaces indicate that the actual gradient does steepen in the vicinity of MW-62.

Because water level data in this region are based upon one water level measurement (MW-62) under pumping conditions, supplemental water level measurements are suggested during the next regularly scheduled maintenance activity. However, as Water Plant 2 appears to be containing the TCE plume at this time, there is no immediate need to terminate pumping and measure water levels to validate this assessment.

4.0 Travel Time Assessment

Initial travel time modeling using the full thickness of the Memphis Sand (600 feet) resulted in much longer travel time scenarios (approximately 18 years). As these data do not correlate with observed transport data onsite, additional credence is given to the effective aquifer thickness theory, suggesting that the hard-packed stringer is contiguous and acting as a aquitard to vertical flow.

As discussed in the *Collierville Site Downgradient Monitoring Well Data Quality Assessment Memorandum*, Section 4.2, an effective aquifer thickness of 200 feet was used to estimate travel times in the vicinity of the Carrier Collierville facility. This judgement was based upon boring log and lithologic data obtained from the Water Plant 2 and the downgradient monitoring wells (MW-60 and MW-62). The uppermost confining layer is defined as the Jackson clay, which ends approximately 90 feet bgs. A lower-permeability sand was encountered at approximately 290 feet bgs, and was described as hard-packed and very-fine-grained.

Although this hard-packed sand stringer is a minor part of the Memphis Sand aquifer, it appears to be contiguous in the vicinity of Water Plant 2 and the downgradient monitoring wells. Due to the significant difference between the very fine-grained sand in this layer, and the medium- to coarse-grained sand observed from the Jackson clay to 290 ft bgs, it is expected that Water Plant 2 wells will derive the majority of their water from the upper 200 feet of the Memphis Sand aquifer. Some vertical communication between the upper, coarser fractions and the lower, finer fractions is to be expected, but is not anticipated to contribute the majority of well yield.

Travel time assessments performed using the effective aquifer thickness of 200 feet agree well with observed contaminant transport in the Memphis Sand aquifer, indicating that under pumping conditions advective transport from the source area to Water Plant 2 would take 6 years. As GW-Path calculations to not account for chemical diffusion/dispersion or biodegradation in the aquifer, actual transport times are typically expected to be longer than estimated. To compare travel time data with historical evidence, TCE first appeared in Water Plant 2 wells in 1986, roughly 7 years after the spill in the main plant area. Given that some time was required for TCE to migrate into the Memphis Sand (not predicted using GW-Path), observed and estimated values (7 years, 6 years) correlate well.